PCT WORLD INTELLECTUAL PROPERTY ORGANIZATION
International Bureau

INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification 7 : G01N 21/89 // 33/34, D21G 9/00 — A1

(11) International Publication Number: WO 00/45156

(43) International Publication Date: 3 August 2000 (03.08.00)

(21) International Application Number: PCT/FI00/00059

(22) International Filing Date: 28 January 2000 (28.01.00)

(30) Priority Data:
990159 28 January 1999 (28.01.99) FI

(71) Applicant *(for all designated States except US)*: NELES PAPER AUTOMATION OY [FI/FI]; Lentokentänkatu 11, FIN–33900 Tampere (FI).

(72) Inventor; and

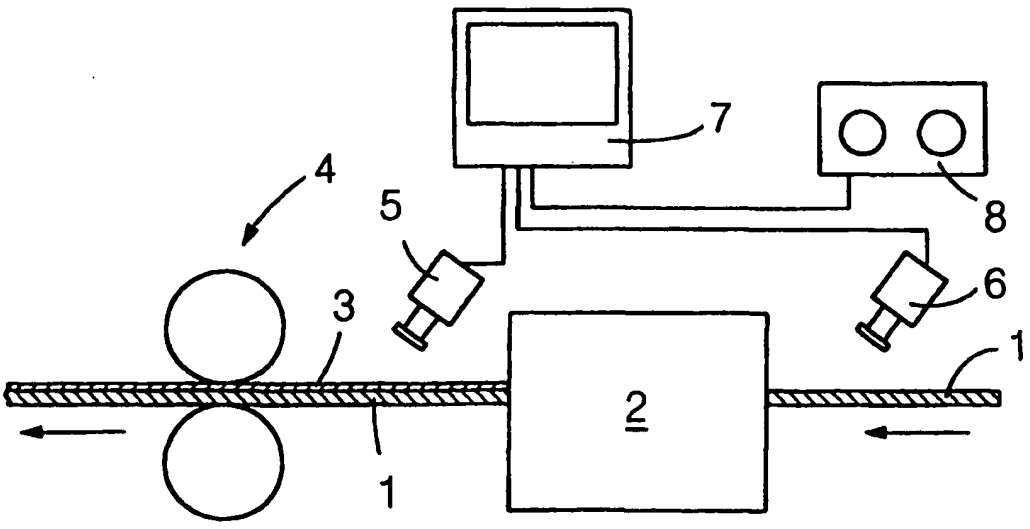
(75) Inventor/Applicant *(for US only)*: KARJANMAA, Jari–Matti [FI/FI]; Mielikinkatu 20, FIN–05830 Hyvinkää (FI).

(74) Agent: KOLSTER OY AB; Iso Roobertinkatu 23, P.O. Box 148, FIN–00121 Helsinki (FI).

(81) Designated States: AE, AL, AM, AT, AT (Utility model), AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CR, CU, CZ, CZ (Utility model), DE, DE (Utility model), DK, DK (Utility model), DM, EE, EE (Utility model), ES, FI, FI (Utility model), GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KR (Utility model), KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SK (Utility model), SL, TJ, TM, TR, TT, TZ, UA, UG, US, UZ, VN, YU, ZA, ZW, ARIPO patent (GH, GM, KE, LS, MW, SD, SL, SZ, TZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG).

Published
With international search report.
In English translation (filed in Finnish).

(54) Title: METHOD FOR MONITORING QUALITY OF PAPER WEB



(57) Abstract

A method for monitoring the quality of a paper web in a continuous process. In the method, a moving paper web is imaged with a thermal camera, whereby the web areas that differ from the moisture level of the surrounding areas or the areas whose coating differs in quantity from the rest of the coated web can be detected in the thermal camera image, and on this basis the process can be controlled to achieve a better end result.

FOR THE PURPOSES OF INFORMATION ONLY

Codes used to identify States party to the PCT on the front pages of pamphlets publishing international applications under the PCT.

AL	Albania	ES	Spain	LS	Lesotho	SI	Slovenia
AM	Armenia	FI	Finland	LT	Lithuania	SK	Slovakia
AT	Austria	FR	France	LU	Luxembourg	SN	Senegal
AU	Australia	GA	Gabon	LV	Latvia	SZ	Swaziland
AZ	Azerbaijan	GB	United Kingdom	MC	Monaco	TD	Chad
BA	Bosnia and Herzegovina	GE	Georgia	MD	Republic of Moldova	TG	Togo
BB	Barbados	GH	Ghana	MG	Madagascar	TJ	Tajikistan
BE	Belgium	GN	Guinea	MK	The former Yugoslav Republic of Macedonia	TM	Turkmenistan
BF	Burkina Faso	GR	Greece	ML	Mali	TR	Turkey
BG	Bulgaria	HU	Hungary	MN	Mongolia	TT	Trinidad and Tobago
BJ	Benin	IE	Ireland	MR	Mauritania	UA	Ukraine
BR	Brazil	IL	Israel	MW	Malawi	UG	Uganda
BY	Belarus	IS	Iceland	MX	Mexico	US	United States of America
CA	Canada	IT	Italy	NE	Niger	UZ	Uzbekistan
CF	Central African Republic	JP	Japan	NL	Netherlands	VN	Viet Nam
CG	Congo	KE	Kenya	NO	Norway	YU	Yugoslavia
CH	Switzerland	KG	Kyrgyzstan	NZ	New Zealand	ZW	Zimbabwe
CI	Côte d'Ivoire	KP	Democratic People's Republic of Korea	PL	Poland		
CM	Cameroon	KR	Republic of Korea	PT	Portugal		
CN	China	KZ	Kazakstan	RO	Romania		
CU	Cuba	LC	Saint Lucia	RU	Russian Federation		
CZ	Czech Republic	LI	Liechtenstein	SD	Sudan		
DE	Germany	LK	Sri Lanka	SE	Sweden		
DK	Denmark	LR	Liberia	SG	Singapore		
EE	Estonia						

METHOD FOR MONITORING QUALITY OF PAPER WEB

The invention relates to a method for monitoring the quality of a paper web in a continuous process, wherein the paper web exiting the actual paper machine is conveyed for treatment.

Depending on the final use of the paper, a paper web to be manufactured on a paper machine can be treated in a variety of ways even when the web is relatively dry. For instance, when manufacturing common newsprint, its surface is smoothed with a so-called machine calender, whereby sufficient surface smoothness for printing is achieved quickly and economically without coating. Certain magazine paper grades in turn require coated paper, whereby the paper web is coated with coating paste containing e.g. china clay or talcum. Very often the coated paper grades are also calendered, i.e. smoothed after coating.

Currently, the paper web calendering and/or coating poses a number of quality problems which result in products that are of poor or varying quality, or worse still, in damaging the coater, particularly the calender rolls thereof, which further results in interruptions in production and repair costs.

In online calendering the web, such as paper, is smoothed as it exits the actual paper machine. In online coating the web is coated as it is produced, i.e. the produced web exiting the paper machine is conveyed directly to coating and further to calendering to the effect that the final result is a finished coated web.

Frequent problems with the web are wet spots and patches where the web is unbroken but wet. These result in web curling and waviness in the final product. Likewise, in conjunction with coating, problems with runability and consequently interruptions in production occur. A further consequence is a small-scale variation in amounts of coating, which results from the fact that the coating attaches to the dry web in a different manner than to wet spots, and the variation being irregular, it does not even show in laboratory tests. Moreover, in the worst case, one consequence may be that in the wet area the coating will not adhere to the web serving as base paper, but it will detach in calendering stage and stick to the surface of a calender roll, and as a result, a hot area forms on the roll having a polymer surface and destroys the roll's surface material.

Furthermore, narrow, less than 10 mm wide, wet streaks appear in the web, as a result of which the paper web shrinks unevenly, and conse-

quently the runability through the whole paper machine, also the coater and later the cutters, deteriorates and waves may form in sheet piles. A further consequence is that amounts of coating vary in different ways in coating and that produces streakiness in the final product. Also in this case the coating at the streaks may adhere to the calender rolls, as a result of which the roll's surface material heats up locally and will be completely destroyed.

Irregular and quick deviations may also occur in coating, which are a common cause of quality variations in coated papers. In post-coating calendering, the coating material may also stick to the calender rolls, since drying is commonly carried out according to an average amount of coating. With time, this may also damage the roll's surface material and lead to a roll change. The CD or MD profile of the paper may also vary excessively. These profile defects may be produced in the wire section, due to wire or felt congestion, in the press section, e.g. by the action of fouled press rolls. These affect the paper formation and thereby the paper profile. In the drying section, suction rolls may produce streaks in the web and thereby affect the profile.

Defect detectors used in paper mills are often based on visible light or on measuring the temperature and moisture of the web. These measurings are typically performed with slow, spot-like sensors. These enable monitoring of long-term variations in the web, but quickly changing defects and deviations remain unnoticed in practice.

German Patent DE 19 63 2988 discloses a solution, in which clearly visible defects, such as tears, light or dark spots, etc., are sought in the web with a conventional video camera by means of bright light. Said publication also discloses a solution, in which the web is monitored either by a conventional IR sensor beam or conventional CCD cameras in order to find similar defects visible to the naked eye and to mark them in the web by spraying marking substance at defects. However, these solutions described in the publications do not allow monitoring moisture defects in the web or variations in the amounts of coating, both of which are often extremely harmful.

The object of the present invention is to provide a method by which the web quality can be monitored more reliably than previously and the causes of various defects can be found in fault situations, whereby they can be eliminated. The method of the invention is characterized in that the moving paper web is imaged with a thermal camera prior to and/or during the treatment substantially continuously in order to detect defects in the paper web and that on

the basis of the detected defects the manufacturing process of the paper web process is adjusted.

The basic idea of the invention is that before and/or after coating the web is monitored substantially continuously with a camera operating within an infrared region, preferably from 3 to 12 micrometer in wavelength. Monitoring can be implemented both as continuous imaging displayed on a monitor and as recording of a camera image such that when a defect or a possible damage appears, it is possible to find the cause of said defect in order that it could be eliminated in one way or another. One preferred embodiment of the invention employs a camera that shows a continuous, non-stop picture of the target to be imaged. Another preferred embodiment of the invention employs a camera that takes a so-called still picture of the target to be imaged at suitably frequent intervals to the effect that if a defect appears it can be rapidly handled. In particular, the invention is applicable to quality control of the web that is already coated or is being coated.

The invention has an advantage that the quality of the finished web product can be ensured. At the same time, it is possible to get quick information on deviations occurring in the process and on the basis thereof the process can be quickly adjusted. Likewise, in situations which may have serious consequences the process can be stopped, the calender opened quickly, if necessary, et cetera, in order for the costs to remain as low as possible. The method of the invention further allows detecting possible, dangerous deviations in the web in conjunction with online calendering and thus localizing the origin of the deviation.

The invention will be described in greater detail in the attached drawing and images, wherein

Figure 1 shows a schematic view of equipment applicable to the implementation of the method of the invention;

Figures 2a and 2b are images of quality deviations in an uncoated web detected with the equipment of Figure 1;

Figure 3 shows deviations in the uncoated web detected after so-called intermediate calendering;

Figure 4 shows the web at the coating station; and

Figure 5 shows the coated web.

Figure 1 is a schematic view of equipment applicable to the implementation of the method of the invention. In the figure, an uncoated web 1 ex-

iting a paper machine is conveyed to a coating unit 2. In the coating unit 2, a coating 3 is applied onto the surface of the web 1, whereafter the coated web is conveyed to calendering 4 and therefrom to further processing. In the coating unit, which is known per se and obvious to the person skilled in the art, coating is applied on the web and spread such that the coated surface of the web is substantially even. In calendering, the coated web is conveyed between hot rolls such that it becomes as even as possible and dries further. In general, the calender rolls are coated with a polymer surface material that is sufficiently elastic and enables even pressing during the calendering.

To implement the method of the invention, the equipment comprises one or more cameras 5 and 6 operating within the infrared region. With these cameras the web 1 can be imaged before or after coating. From the camera or cameras 5,6 the image is conveyed to a monitor 7, for instance, which the operation controller of the equipment can watch. Additionally or alternatively, the image can be conveyed to a recorder 8 which records the image provided by the camera or cameras substantially continuously.

When deviations of a given type, such as wet spots or patches, streaks of moisture, etc., are detected in the web 1 or irregularities are detected in the amount of coating, the process can be immediately adjusted or stopped, if there is any reason to assume that the detected defects would cause serious damage and thereby costs to the equipment. On the basis of the deviations and defects it is further possible to trace the origin of the deviation and hence the quality of the process and its end product can be improved and the interruption and damage costs incurred can be avoided considerably.

Figures 2a and 2b show defects detected with the equipment of Figure 1. The images have been taken of the web 1 in the manner according to the invention, i.e. of the base paper before it is conveyed to a coating station. Figure 2a shows how the moisture level of the web exiting an unserviced machine, for instance due to congested felts, is high and variations are considerable. Conventional online paper measuring devices based on spot detection cannot detect these defects. Instead, from Figure 2b it appears that moisture variations are minor, which indicates that the felts and the paper machine are serviced and in good condition.

Figure 3 shows narrow streaks of moisture in the web 1, i.e. in the base paper. This image was taken of the web 1, i.e. the base paper, after so-called intermediate calendering, and the narrow streaks of moisture indicated

by a reference numeral 9 are clearly visible. Black spots, indicated by a reference numeral 10, also appear in the image, which reveal irregular quality deviations in the web 1.

Figure 4 shows the web, i.e. the base paper, at the coating station, and the image reveals a plurality of different facts. Striping caused by the rolls is indicated with the reference numeral 9 like in Figure 3. A marking 11 caused by a felt seam appears also from the image. A pattern 12 produced by latex spots on the opposite side of the web appears also from the image, which indicates defects in the coating.

In Figure 5, the amount of coating varies in different parts of the web. In this case, there is clearly more coating in some areas than in others, and consequently, the coating dries more slowly in said areas than elsewhere in the paper. As a result, the coating may still be too wet in calendering, whereby the coating may stick to the calender roll's surface that will damage completely with time.

The images used by way of example were taken by a camera operating within an infrared region of 3 to 12 micrometer in wavelength. The measuring regions are preferably from 3 to 5 micrometer or 8 to 12 micrometer, whereby various defects and deviations can be detected in a variety of ways. However, it is essential that by using a thermal camera operating within the infrared region in this manner various defects and deviations can be detected both in the uncoated web and in the coating material of the coated web, which defects and deviations may cause quality variations in the product or even damage to the coating equipment, in particular, in the calender roll's surface material and thus inflict considerable expenses on production, both as downtime and as repair costs of the equipment.

In the above specification and drawings, the invention has only been described by way of example and it is by no means restricted thereto. It is substantial that the quality of the web to be coated is monitored with cameras operating within the infrared region either such that the web exiting the paper machine is monitored before coating or the quality of the coating material of the coated paper is monitored before calendering substantially continuously such that the manufacturing process of the paper web product can be adjusted either on the actual paper machine or in the treatment thereafter in order to obtain a product of as high quality as possible.

CLAIMS

1. A method for monitoring the quality of the paper web in a continuous process, wherein the paper web exiting the actual paper machine is conveyed for treatment, **characterized** in that the moving paper web is imaged with a thermal camera prior to and/or during the treatment substantially continuously in order to detect defects in the paper web and that on the basis of the detected defects the manufacturing process of the paper web product is adjusted.

2. A method as claimed in claim 1, **characterized** by monitoring the web that is calendered immediately upon manufacturing.

3. A method as claimed in claim 1 or 2, **characterized** by monitoring the web that in conjunction with the actual web manufacturing will be finally coated with a coating layer.

4. A method as claimed in any one of preceding claims 1 to 3, **characterized** by monitoring wet spots and patches in the web and/or wet streaks of the web.

5. A method as claimed in claim 3 or 4, **characterized** by monitoring the web before and/or after the coating of the web.

6. A method as claimed in any one of claims 1 to 5, **characterized** in that the imaging is performed within the infrared light spectrum of 3 to 12 micrometer in wavelength.

7. A method as claimed in any one of claims 1 to 6, **characterized** in that the imaging is performed with a video camera on a continuous basis.

8. A method as claimed in any one of claims 1 to 6, **characterized** in that the imaging is performed by taking still pictures at predetermined intervals on a substantially continuous basis.

9. A method as claimed in any one of preceding claims, **characterized** in that the image is continuously displayed on a monitor so as to enable continuous monitoring during the process.

10. A method as claimed in any one of preceding claims, **characterized** in that the image and/or images are stored in the memory for further analyzing.

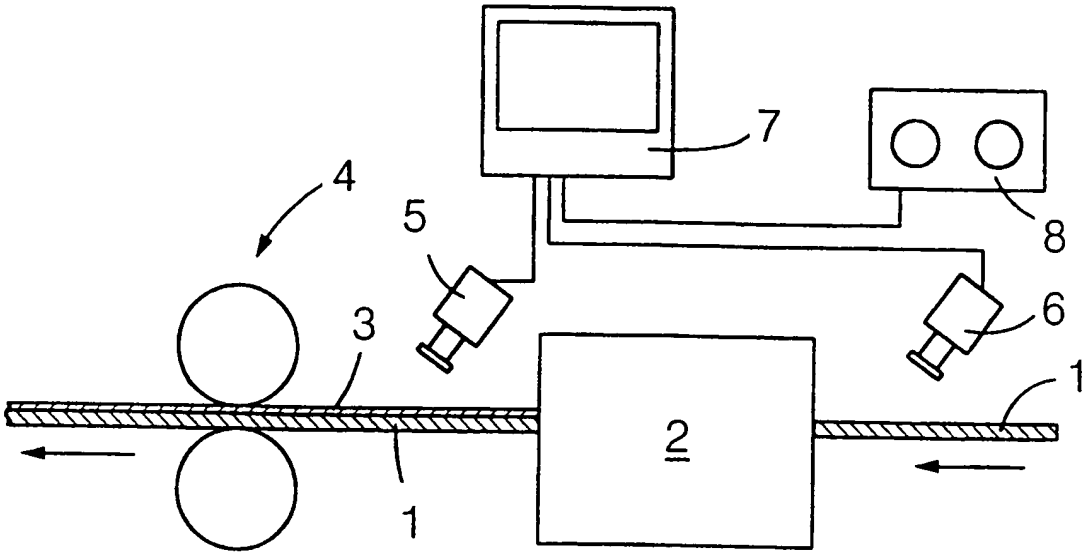


FIG.1

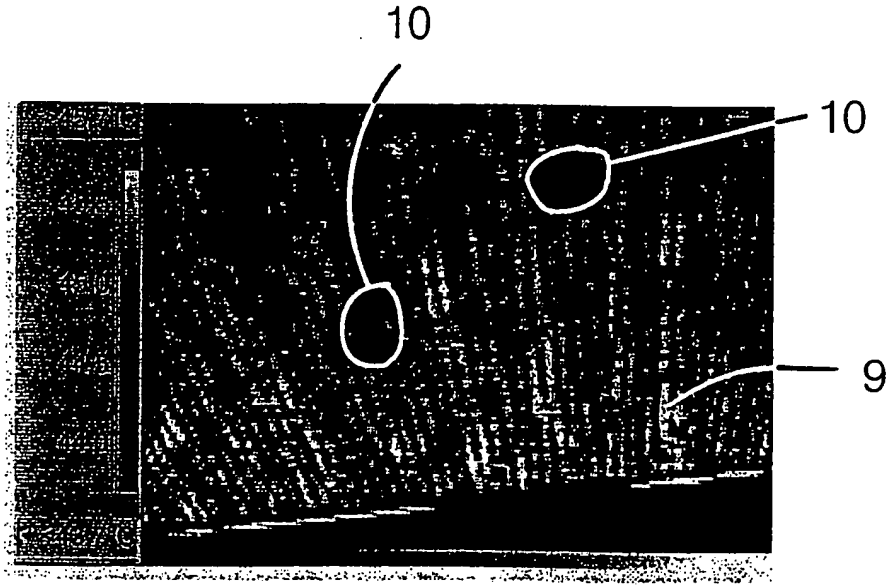


FIG.3

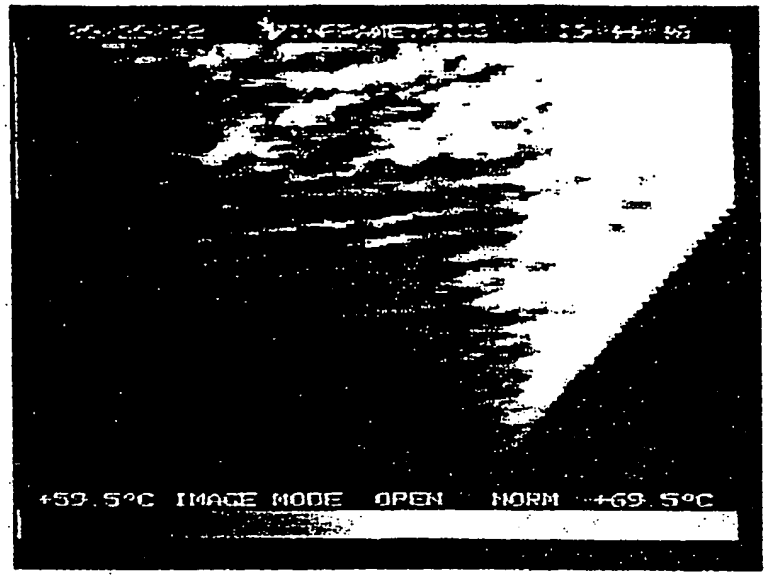


FIG. 2a

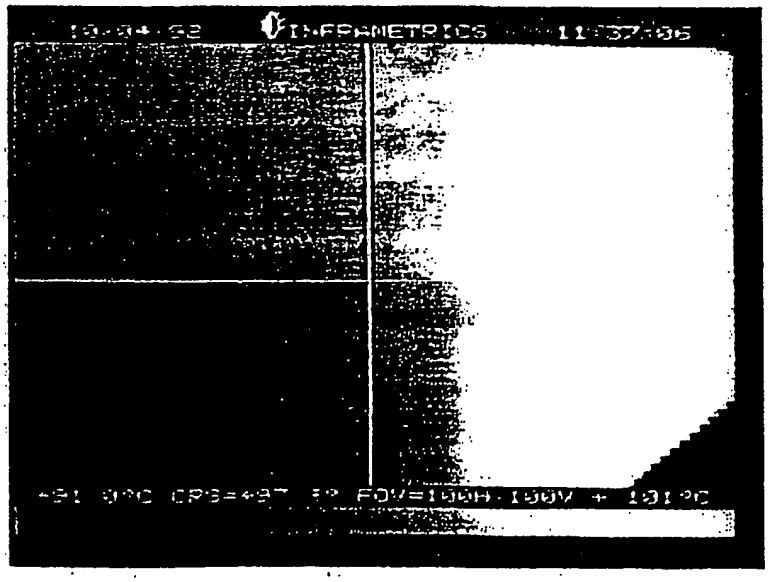


FIG. 2b

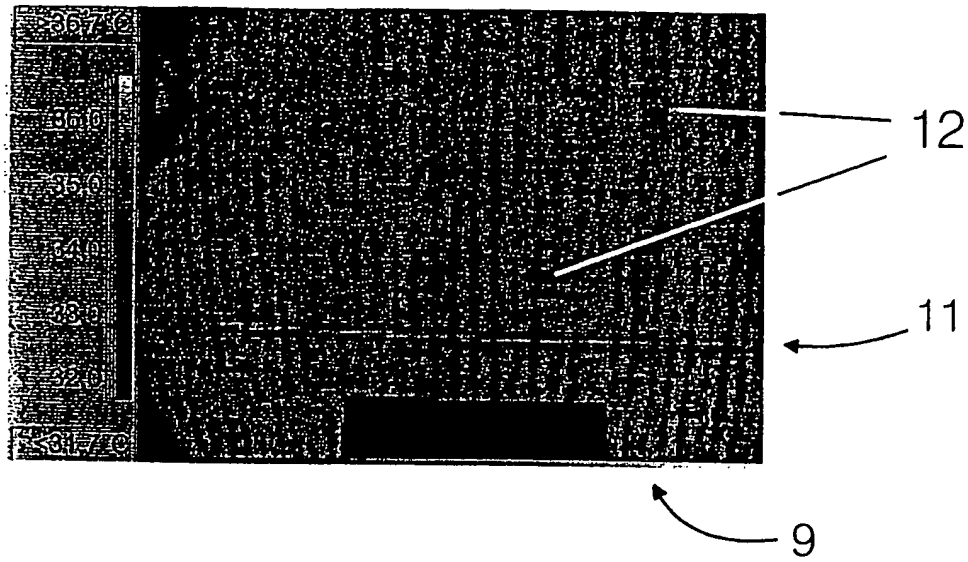


FIG. 4

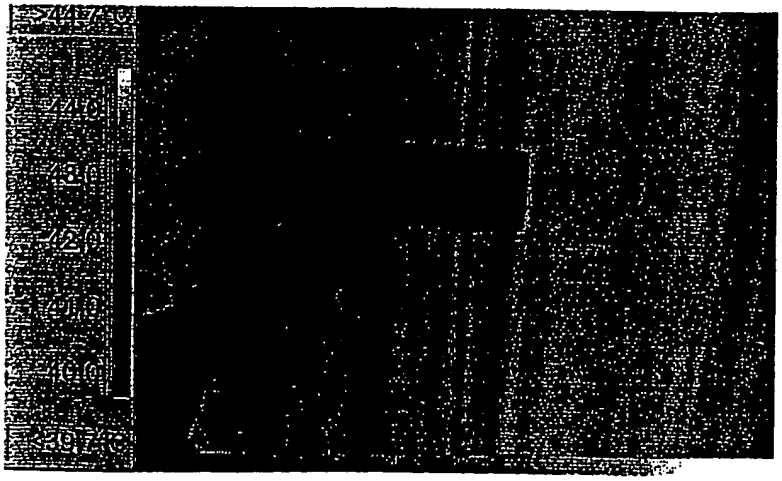


FIG. 5

INTERNATIONAL SEARCH REPORT

International application No.
PCT/FI 00/00059

A. CLASSIFICATION OF SUBJECT MATTER

IPC7: G01N 21/89 // G01N 33/34, D21G 9/00
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC7: G01N, D21G

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

SE,DK,FI,NO classes as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

WPI EPODOC

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 5822070 A (H-R.SYRE), 13 October 1998 (13.10.98), column 2, line 47 - line 67, figure 1 --	1-10
X	US 5821990 A (R.J.RUDT ET AL), 13 October 1998 (13.10.98), column 5, line 5; ~~26~~ column 7, line 22 - column 8 line 63 --	1-10
X	TAPPI, Volume 67, No 12, 1978, DENNIS E.VICKERY ET AL, "INFRARED THERMOGRAPHY.An aid to solvning paper machine moisture profile problems.", page 17 - page 20, see the whole article --	1-10

[X] Further documents are listed in the continuation of Box C. [X] See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" erlier document but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance: the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance: the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
10 April 2000	17-05-2000
Name and mailing address of the ISA/	Authorized officer

INTERNATIONAL SEARCH REPORT

International application No.
PCT/FI 00/00059

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 5696591 A (R.B.BILHORN), 9 December 1997 (09.12.97), column 1, line 6 - line 10; column 4, line 52 - line 67	1-10
A	US 5118195 A (W.DOBBIE), 2 June 1992 (02.06.92)	1-10
A	US 4500968 A (W.L.BIALKOWSKI), 19 February 1985 (19.02.85), figure 2, abstract	4
A	DE 19632988 C1 (STORA PUBLICATION PAPER AG), 22 January 1998 (22.01.98)	1-10

INTERNATIONAL SEARCH REPORT

Information on patent family members

02/12/99

International application No.
PCT/FI 00/00059

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 5822070 A	13/10/98	AT 166154 T	15/05/98
		DE 4422861 A,C	04/01/96
		DE 59502182 D	00/00/00
		EP 0767904 A,B	16/04/97
		SE 0767904 T3	
		FI 965245 A	30/12/96
		WO 9600894 A	11/01/96
US 5821990 A	13/10/98	AU 706773 B	24/06/99
		AU 3827495 A	23/09/96
		BR 9510548 A	09/06/98
		CA 2214724 A	12/09/96
		EP 0813703 A	29/12/97
		FI 973611 A	04/11/97
		JP 11502645 T	02/03/99
		NO 974012 A	08/09/97
		NZ 295027 A	24/11/97
		US 5717456 A	10/02/98
		WO 9627825 A	12/09/96
		ZA 9509613 A	19/06/96
US 5696591 A	09/12/97	NONE	
US 5118195 A	02/06/92	NONE	
US 4500968 A	19/02/85	NONE	
DE 19632988 C1	22/01/98	CN 1228132 A	08/09/99
		CZ 9900488 A	14/07/99
		EP 0922139 A	16/06/99
		NO 990605 A	09/02/99
		PL 331586 A	19/07/99
		WO 9806897 A	19/02/98